STUDY OF MAXIMUM POWER POINT TRACKING ALGORITHMS AND IDENTIFICATION OF PEAK POWER USING COMBINED ALGORITHM FOR PHOTOVOLTAIC SYSTEM

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ABSTRACT: *There are many methods used to track maximum power point (MPP) of photo voltaic (PV) array. This paper presents a study and review of different techniques of peak power point tracking algorithms for photo voltaic array. In this paper proposed new combined algorithm for rapid tracking photovoltaic system . There are two stages, first stage algorithm fast tracking and fine tracking in second stage. It has combination of perturb and observe algorithm and current sweep. By using this combination drawback of this two types cancel each other and give real maximum power point tracking in rapid changing environmental condition i.e. temperature and solar radiation.*

Keywords: Maximum power point tracking (MPPT), Perturb and observe (P & O), Current sweep, Photovoltaic (PV).

1. INTRODUCTION

Now days, power demand is one of the major problem in whole world. Due to unavailability of enough resource to give power, so renewable energy sources such as solar energy, wind energy are widely used. Solar energy is used for many applications such as battery charging, solar pumping, solar heating, home power supply, satellite power system etc. which have pollution and maintenance free. But initial investment cost of solar equipment is high, it require charger/ inverter for any application. Since solar array have low conversion efficiency. So overall cost of system is reduced by designing converter which gives maximum efficiency of photovoltaic array. Which call maximum power point tracker.[1]

Maximum power point tracker (MPPT) which tracks continuously maximum power point that point have maximum voltage V_m and maximum current I_m of photovoltaic array. Many MPPT algorithm have been studied and developed such as fractional open circuit, fractional short circuit, current sweep, perturb and observe (P & O), incremental conductance. The P & O algorithm is most commonly used to track MPP. Because of easy implement track MPP. But practically this algorithm does not track real MPP on rapid changing environmental condition i.e. solar radiation and temperature. Drawback of P&O is overcome by using incremental conductance technique but this is complex algorithm and difficult to implement. [6] Current sweep technique gives fast tracking but its require periodically track the MPP. Its fails when solar irradiation and temperature variation happen.

This paper presents a new approach or propose algorithm that two stage algorithm. First stage fast tracking and second stage fine tracking. It is combination of perturb and observe technique and current sweep MPP tracking methods. The proposed algorithm identify quickly and accurately the MPP in non-ideal environmental condition.

2. PV MODULE AND CHARACTERISTICS

The equivalent circuit of a PV module is shown in Fig. 1(a), while typical output characteristics are shown in Fig. 1(b). The characteristic equation for this PV model is given by [1],

$$\mathrm{I} = I_{LG} - I_{OS} - \left\{exp\left[\frac{q}{AkT}\left(\mathrm{V} - IR_S\right)\right] - 1\right\} - \frac{V + IR_S}{R_{SH}}$$

where

$$I_{OS} = I_{Or}\left[\frac{T}{Tr}\right]^3 exp\left[\frac{qE_{GO}}{Bk}\left(\frac{1}{Tr} - \frac{1}{T}\right)\right]$$

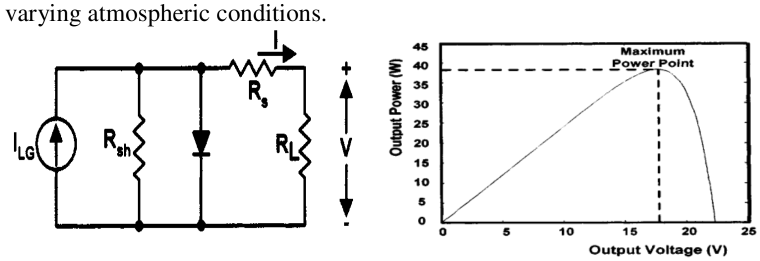
$$I_{LG} = \left[I_{SCR} + K1(T - 25)\right]\lambda/100$$

And

I and V cell output current and voltage;

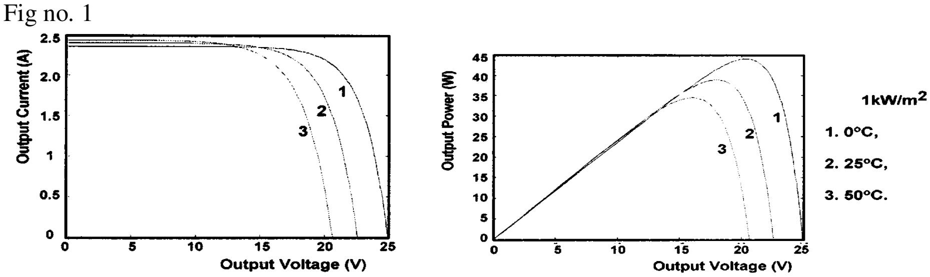
I_{OS}	cell reverse saturation current;
T	cell temperature in ^oC;
k	Boltzmann's constant;
q	electronic charge;
K_I=0.0017 A/^{o}C	short circuit current temperature coefficient at I_{SCR} ;
λ	solar irradiation in W/m^2 ;
I_{SCR}	short-circuit current at 25^{o}C and 1000 W/m^2 ;
I_{LG}	light-generated current;
E_{GO}	band gap for silicon;
B=A=1.92	ideality factors;
T_r=301.18^{o}K	K reference temperature;
I_{or}	cell saturation current at T_r ;
R_{sh}	shunt resistance;
R_s	series resistance.

The variation of the output I-V characteristics of a commercial PV module as function of temperature and irradiation is shown in Fig. 2 (a) & (b) and Fig. 3(a) & (b), respectively. It is seen that the temperature changes affect mainly the PV output voltage, while the irradiation changes affect mainly the PV output current. The intersection of the load-line with the PV module I-V characteristic, for a given temperature and irradiation, determines the operating point. The maximum power production is based on the load-line adjustment under varying atmospheric conditions.



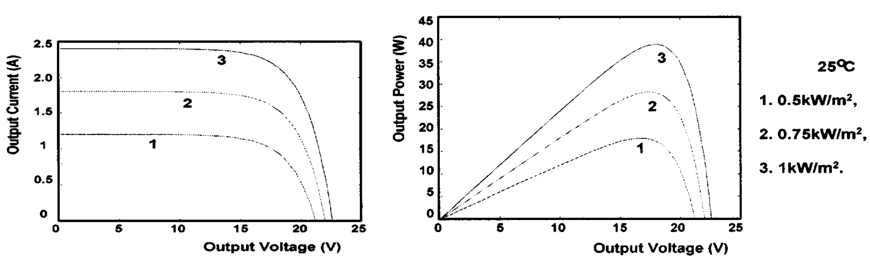
(a) Equivalent circuit of a PV module (b) typical PV module current-voltage characteristics

Fig no. 1



(a) **(b)**

Fig No.2 characteristic of a PV module with constant irradiation and varying temperature



(a) **(b)**

Fig No. 3 Characteristics of a PV module with constant temperature and varying irradiation.

3. PROBLEM OVERVIEW

PV module characteristics shows maximum power point at which has maximum voltage and maximum current. MPPT algorithms tracks continuously that point in variation of solar irradiation and temperature also and under partial shading condition.

MPPT Algorithm

We introduce different MPPT techniques below.

1) Fractional Open Circuit Voltage :-

Photovoltaic have near linear relationship between V_{mmp} and V_{OC}

$V_{mpp} \approx K1\ V_{OC}$

Where K1 is constant of proportionality, since K1 is dependent on characteristic of PV array. Factor K1 has been in range between 0.71 to 0.78.[2],[4]

In this method V_{OC} is calculated by disconnecting solar array from DC-DC converter. Then calculate the V_{mmp} using K1 factor. So, this system have temporary loss power when it calculate V_{OC}. K1 factor is no more valid under partial shading condition and charging solar radiation.

2) Fractional Short Circuit Current:-

I_{mmp} is also linearly function with I_{SC} i.e. short circuit current of PV array.

$I_{mmp} \approx K2\ I_{SC}$

Where K2 is proportionality constant. It has range in between 0.78 to 0.92. In this technique I_{SC} is calculated by periodically short circuit the PV array to track the I_{mmp}. This increases number of components and cost. .[2],[4]

3) Perturb And Observe (P & O):-

P & O techniques work periodically incrementing or decrementing the voltage of PV array. The change in power is observed. If perturbation has observed increases in PV power then it continuous to perturb in same direction, if it is decreases then the perturb in opposite direction. See flow chart. P+ & O means it observe PV power and compare new power with old power. According to that it increases or decreases duty cycle to gate maximum power point. .[2],[4],[5]

P & O algorithm is simple to implement but in rapidly Changing solar radiation condition it oscillates around MPP.

4) Incremental conductance –

Drawback of P & O is overcome by incremental conductance technique. Incremental size decide fast tracking if we use more size then it oscillate MPP & not track the exact MPP. The incremental conductance (IncCond) method is based on the fact that the slope of the PV array power curve (Fig. 1(c)) is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by .[2],[3],[4]

$$\begin{cases} \mathrm{dP/dV} = 0\text{, at MPP} \\ \mathrm{dP/dV} > 0\text{, } left\ of\ MPP \\ \mathrm{dP/dV} < 0\text{, } right\ of\ MPP \end{cases} \qquad (1)$$

Since

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \approx \mathrm{I} + \mathrm{V}\frac{\Delta I}{\Delta V} \qquad (2)$$

(1) can be rewritten as

$$\begin{cases} \Delta\mathrm{I}/\Delta\mathrm{V} = 0\text{, at MPP} \\ \Delta\mathrm{I}/\Delta\mathrm{V} > 0\text{, } left\ of\ MPP \\ \Delta\mathrm{I}/\Delta\mathrm{V} < 0\text{, } right\ of\ MPP \end{cases} \qquad (3)$$

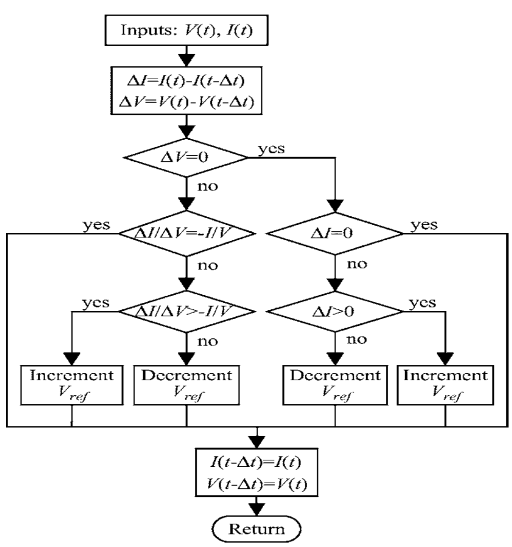


Fig. 4. IncCond algorithm as shown in [2]

The MPP can thus be tracked by comparing the instantaneous conductance (*I/V*) to the incremental conductance ($\Delta I/\Delta V$) as shown in the flowchart in Fig. 4. *Vref* is the reference voltage at which the PV array is forced to operate. At the MPP, *Vref* equals to *VMPP*. Once the MPP is reached, the operation of the PV array is maintained at this point unless a change in ΔI is noted, indicating a change in atmospheric conditions and the MPP. The algorithm decrements or increments *Vref* to track the new MPP.

5) Current sweep -

The current sweep [2][8] method uses a sweep waveform for the PV array current such that the *I V* characteristic of the PV array is obtained and updated at fixed time intervals. The *VMPP* can then be computed from the characteristic curve at the same intervals. The function chosen for the sweep waveform is directly proportional to its derivative as in

$$f(\mathrm{t}) = k_4 \frac{df(t)}{dt} \qquad (1)$$

Where k_4 is a proportionality constant. The PV array power is thus given by

$$P(t)=v(t)i(t)=(t)f(t) \qquad (2)$$

At the MPP

$$\frac{dp(t)}{dt} = \mathrm{v(t)} + \mathrm{f(t)}\frac{dv(t)}{dt} = 0 \qquad (3)$$

Substituting (1) in (3) gives

$$\frac{dp(t)}{dt} = \left[\mathrm{v(t)} + \frac{dv(t)}{dt}\right]\frac{df(t)}{dt} = 0 \qquad (4)$$

The differential equation in (1) has following solution

$$f(t) = Cexp[t/k_4] \qquad (5)$$

C is chosen to be equal to the maximum PV array current Imax and $k4$ to be negative, resulting in a decreasing exponential function with time constant $\tau = -k4$. Equation (5) leads to

$$f(t) = I_{MAX}exp[-t/\tau] \qquad (6)$$

The current in (6) can be easily obtained by using some current discharging through a capacitor. Since the derivative of (6) is nonzero, (4) can be divided throughout by $df(t)/dt$ and, with $f(t) = i(t)$, (4) simplifies to

$$\frac{dp(t)}{di} = \mathrm{v(t)} + k_4\frac{dv(t)}{dt} = 0 \qquad (7)$$

Once *VMPP* is computed after the current sweep, (7) can be used to double check whether the MPP has been reached. In [2], the current sweep method is implemented through analog computation. The current sweep takes about 50 ms, implying some loss of available power. In [2], it is pointed out that this MPPT technique is only feasible if the power consumption of the tracking unit is lower than the increase in power that it can bring to the entire PV system.

4. PROPOSED ALGORITHM FOR MPPT

Drawback of P & O is the performance of the Perturb and Observe depends on the sampling interval and the duty-cycle perturbation of the algorithm . Those parameters set the dynamic response of the MPPT, such as speed, accuracy and stability. The duty cycle step must be chosen properly. Since the Perturb and Observe technique oscillates around the maximum power point, reducing the duty cycle step can minimize the oscillation and the steady state losses. However, the controller is less efficient when the atmospheric conditions change rapidly.

The current sweep method manipulates the solar panel current, so during the current sweep there will be reduced power output. The current sweep determines the i-v characteristic of the solar panel and the maximum power point voltage is determined. The controller holds this computed voltage as the operating voltage of the solar panel until the next current sweep determines a new maximum power point voltage. So, the current sweep is not performed continuously, but only periodical. It only makes sense to perform a current sweep if the increase in generated power is greater than the loss of power by performing the current sweep. This is the main consideration for determining the period of the current sweep method.[2],[4]

The proposed algorithm have two stage tracking that offer first stage fast tracking and fine tracking in the second stage .If we combine Perturb and Observe & current sweep method it will be cancel out drawback of each other.Current sweep method gives fast tracking & fine tracking by using P & O with proper duty step size to track the MPPT. Proposed algorithm flow chart shown below Fig no. 5.

It is assumed that the PV module is operated at a given point. The algorithm commands the converter to make a sweep in the modules characteristic. Make the sweep which duty cycle vary 10% to 90% . At this sweep time duration PV_V & PV_I sensed to calculate PV power. In controller make the array for sweep duration which has calculated PV power for each duty %(10% to 90%). Find largest power in that array ,that point is MPP, that power duty used for mpp tracking. Due to drawback of current sweep is not performed continuously, but only periodically use timer for 5 min duration to track MPP continuously but rapid clouds may be present, thus the MPP may change faster than the 'normal operating period'. Besides, if the sweep-duration is too long, the irradiance may have changed and the recorded curve corresponds to two different irradiations. To avoid this use P & O algorithm here. After staring ON the timer for 5 min in this duration use P & O algorithm. It compare new power with old power according to that duty cycle will be increase & decrease to by using proper duty cycle step size to get fine tracking of MPP.

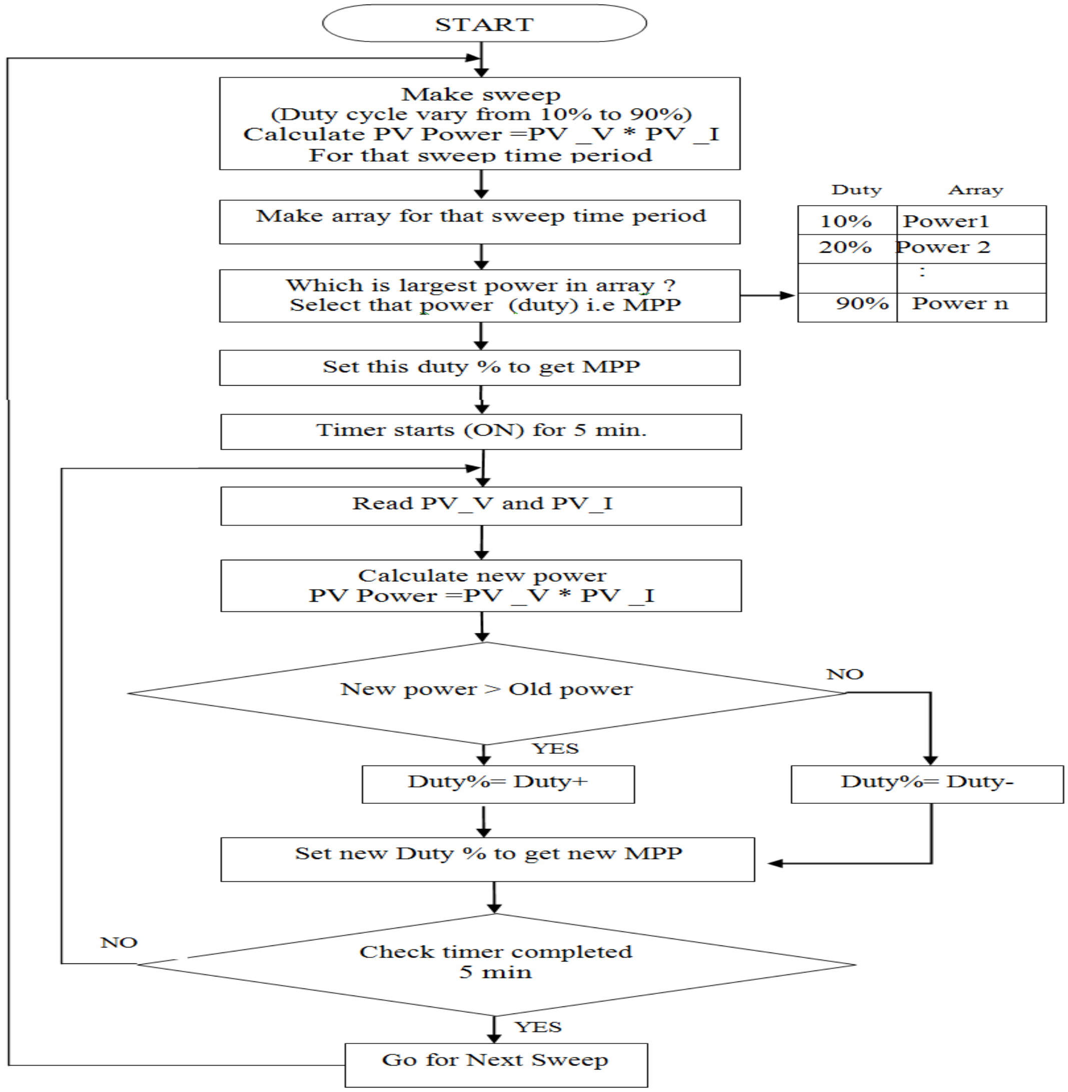


Fig No.5: flow chart of Proposed algorithm

After completing 5 min make the next current sweep to get new MPP & this cycle is repeated for every 5 min.

5. CONCLUSION

The proposed algorithm gives two necessary factor in finding out real maximum power point which are rapid tracking response in rapid changing of climate conditions of solar radiation & temperature compare to traditional algorithm.

The proposed algorithm cancel out the drawback of P & O algorithm & current sweep each other when this two algorithm used in combine form to achieve fast tracking of maximum power point for photovoltaic syatem.

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